NUST JOURNAL OF SOCIAL SCIENCES AND HUMANITIES
Vol.3 No.2 (July-December 2017) pp. 152-177

Decomposition Analysis of Energy Consumption in Pakistan for the Period 1990-2013

Faisal Jamil* and Arbab Shahzad†

Abstract:

The final energy consumption in Pakistan has doubled during the last two decades. Investigating the factors responsible for changes in energy use is important for future projections. Decomposition techniques enable us to quantify the contributing factors in aggregate energy change. This study attempts to investigate the factors behind the aggregate change in energy consumption over the period 1990-2013 using Logarithmic Mean Divisia Index (LMDI) decomposition technique. LMDI decomposes the overall change in energy use into three effects namely, activity, structural, and intensity effects. Results of the study suggest that observed increase in Pakistan's energy consumption is primarily due to the activity and structural effects. The energy intensity of overall economy has decreased showing an increase in energy efficiency, though at a decreasing rate over time. The quantification of energy imports based on projections shows that Pakistan may face serious fiscal challenge by 2025 due to extremely large energy import bill and possible energy price shocks. There is a need to put efforts towards reducing the gap between energy supply and demand, diversifying domestic energy production including increased reliance on renewables, efforts towards energy and environment conservation, and efficient use of available resources.

Keywords: Energy, Decomposition Analysis, LMDI, Intensity Effect

1. INTRODUCTION

Energy is an essential input affecting the output and the overall economic welfare. Various past studies examine the relationship between economic growth and energy consumption and find different results for different economies [Masih and Masih (1996); Soytas and Sari (2003); Lee (2007); Apergis and Payne (2010); Jamil and Ahmad (2010); Belke, *et al.* (2011); and, Shahbaz, *et al.* (2012)]. The literature

* Faisal Jamil <faisal.jamil@s3h.nust.edu.pk> is Assistant Professor at School of Social Sciences and Humanities (S3H), National University of Sciences & Technology (NUST), Islamabad, Pakistan.

† Arbab Shshzad <arbabshahzad90@gmail.com> School of Social Sciences and Humanities (S3H), National University of Sciences & Technology (NUST), Islamabad, Pakistan.

finds that growth in energy consumption is inevitable in the economic growth although there is lack of consensus on the direction of causality.

The final energy consumption in Pakistan increased from 21.58 million tons of oil equivalents (MTOE) in 1990 to 40.18 MTOE in 2013 [Energy Yearbook (2014)]. The role of economic growth is considerable in raising energy consumption. The energy mix and consumer mix for different energy sources are changing over time making the job of policy makers and energy planners challenging. The investigation of changing energy consumption patterns and the factors responsible for this change is an important research topic. Therefore, this study seeks to quantify the impact of structural shift of economic activity on total energy demand in Pakistan so as to have better understanding of the energy use mechanisms.

Energy decomposition is a widely used method that tracks the relative contributions of various factors to changes in energy consumption, energy intensity and the environment [Ang and Zhang (2000); Mairet and Decellas (2009)]. Different decomposition techni-ques have been used in various past studies such as, Arithmetic Mean Divisia Index method-1 (AMDI-1), Modified Fisher Ideal Index method, Conventional Fisher Ideal Index method, Shapley/Sun method and Marshall-Edgeworth method, Laspeyres, Paasche, Sato-Vartia and Tornqvist [Ang and Zhang (2000); Liu and Ang (2003); Ang (2004)]. Some studies provide a comparison of various decomposition methods and show that log mean divisia index (LMDI) method is robust due to being consistent in aggregation, residual free, and easy interpretation. These advantages lead to an extensive use of LMDI in different past studies [Ang and Choi (1997); Ang and Liu (2001); Ang (2004); Ang (2005); Ediger and Huvaz (2006); Ma and Stern (2008); Hatzigeorgiou, *et al.* (2008); Mairet and Decellas (2009); Zhang, *et al.* (2011); Balezentis and Strienikiene (2011); Nasab, *et al.* (2012); Hasanbeigi and Sathaye (2012); Zhao, *et al.* (2012); and Lotz and Pouris (2012)].

LMDI enables to investigate the responsible factors of aggregate energy consumption change over time by decomposing the overall change into certain effects including activity effect, structural effect and intensity effect. The activity effect shows the impact of a change in energy consumption associated with level of economic activity;

structural effect summarizes the impact of composition of energy consuming activities; while, intensity effect highlights the impact associated with sectoral use of energy per unit of output. In a nutshell, literature has established the usefulness of decomposition in energy related forecasting as it helps to track down factors that are responsible for change in aggregate energy use. Most of the past studies decompose either total energy consumption or carry out the analysis for a particular sector especially the manufacturing sector. Moreover, a range of decomposition methods are found in the literature, but a consensus about the best decomposition method is still lacking.

This study applies period-wise decomposition analyses for the total period as well as decade-wise analysis separately for 1990-2000 and 2000-2013 and also quantifies the cost to the economy of the projected energy imports by 2025. The economy is broadly classified into agriculture, industrial and services sectors and energy consumption rises in all the sectors that contributed to the energy imports of Pakistan. The results suggest that observed increase in the energy consumption is primarily attributed to the activity and structural effects. The energy intensity of overall economy shows a decreasing trend signifying improvements in energy efficiency over the period. However, the compensating share of intensity effect was higher during the period 1990-2000 as compared to 2000-2013. The sector-wise analysis shows that agriculture is responsible for a decline in total energy consumption, while industrial and services sectors have contributed in energy consumption growth. The quantification of energy imports based on official projections indicates that the country may face serious balance of payment challenges by 2025 due to heavy reliance on imported energy. It suggests diversifying energy mix towards more renewable and sustainable energy sources.

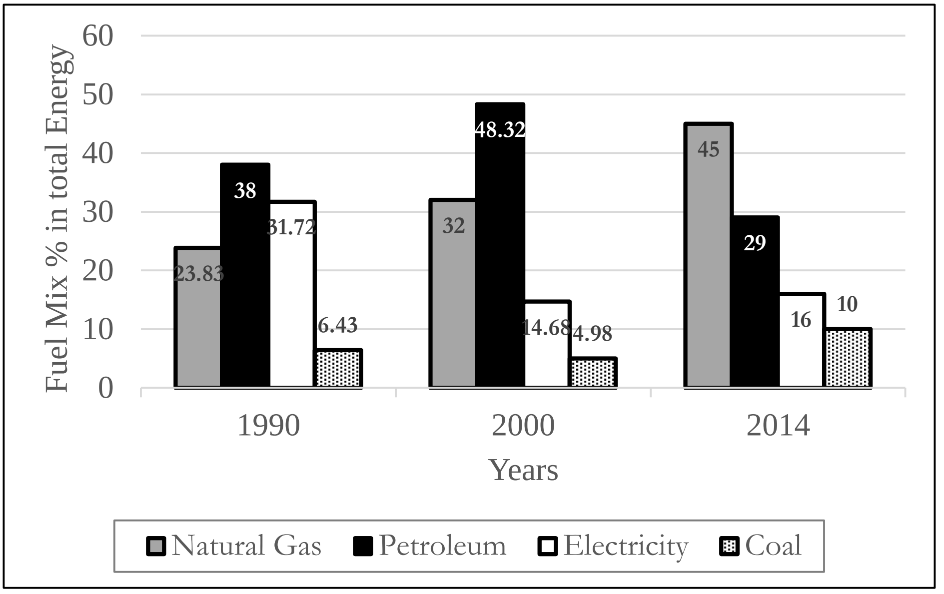
The rest of the paper is as follows. Section 2 provides an overview of energy sector in Pakistan. Section 3 describes the methodology and the data while Section 4 discusses the results. Section 5 shows the impact of future energy imports on Pakistan’s external account. Finally, Section 6 concludes the study.

2. AN OVERVIEW OF PAKISTAN ENERGY SECTOR AND THE ECONOMY

Total final energy consumption is increasing in Pakistan and is projected to reach 142 MTOE by 2025 [Pakistan Integrated Energy Plan (2013)]. The final energy mix is mainly comprised of four sources including natural gas, oil, hydroelectricity and coal. The share of natural gas and oil is about 74% in the total mix. Petroleum imports constitute about 30% of total energy use in Pakistan in 2014 and are increasing as indigenous natural gas resources are depleting. Energy efficiency is the major future energy source in the world. It is valid in the case of Pakistan as the energy intensity calculated by energy use per unit of output has declined over time, from 9.42 TOE in 1990 to 7.09 TOE and 6.64 TOE per unit of output respectively in 2000 and 2014. Figure 1 shows the period-wise changing patterns of Pakistan's fuel mix [Energy Yearbook (2000, 2014)].

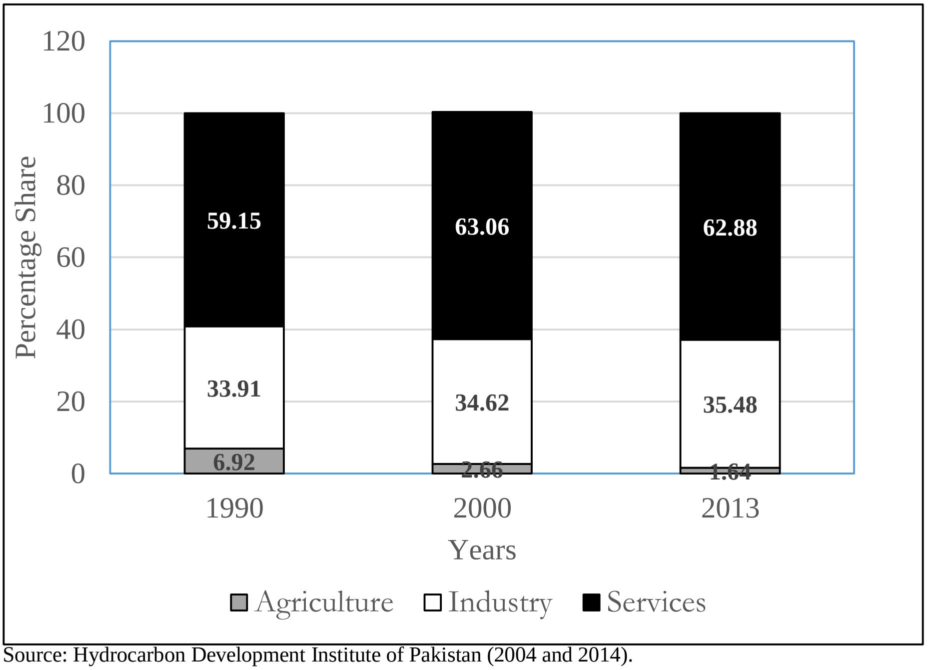
Total energy consumption in different sectors shows changing pattern as the share of agriculture is declining whereas, shares of industry and service sectors have slightly increased (see, Figure 2). A similar pattern is evident in the sector-wise economic activity shares during 1990-2013 as shown in Figure 3. The economy has experienced structural shifts especially during the last decade wherein the share of agriculture in the economy falls and the shares of industry and services sectors increase. The composition of intra-sector economic activity is given in the subsequent figures. Figure 4 depicts the changing pattern of sub-sectoral shares in the agriculture sector. The share of crops in agricultural GDP has fallen from 65 to 42% while, livestock subsector witnessed a phenomenal rise in its share from 30 to 55% over the period. This structural pattern clearly indicates that agricultural sector has been rapidly moving from relatively energy intensive crop sub-sector towards less energy intensive livestock sub-sector. Figure 5 shows the shares of sub-sectors in the industrial sector. Manufacturing sector's share in the total sectoral output has increased from 68% to 73% over the same time period. The other two sub-sectors, i.e., construction and utilities' supply have witnessed decreasing share in total industrial output.

Figure 1. Share of Fuels in total energy Mix in the period 1990-2014



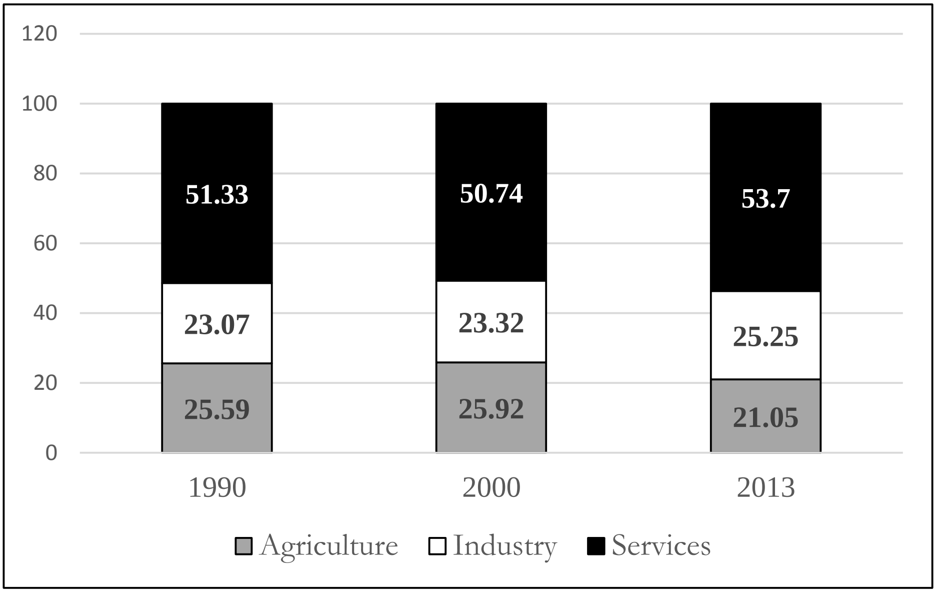
Source: Hydrocarbon Development Institute of Pakistan (2004 and 2014).

Figure 2. Sectoral share in total energy consumption in Pakistan 1990-2013



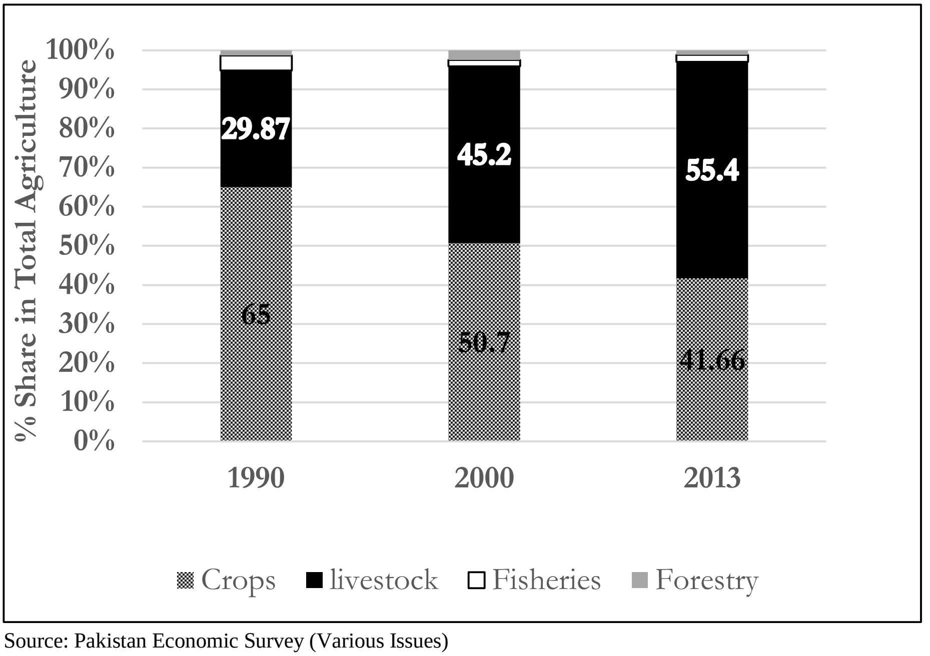
Source: Hydrocarbon Development Institute of Pakistan (2004 and 2014).

Figure 3. Sectoral share of Economic Activity 1990-2013



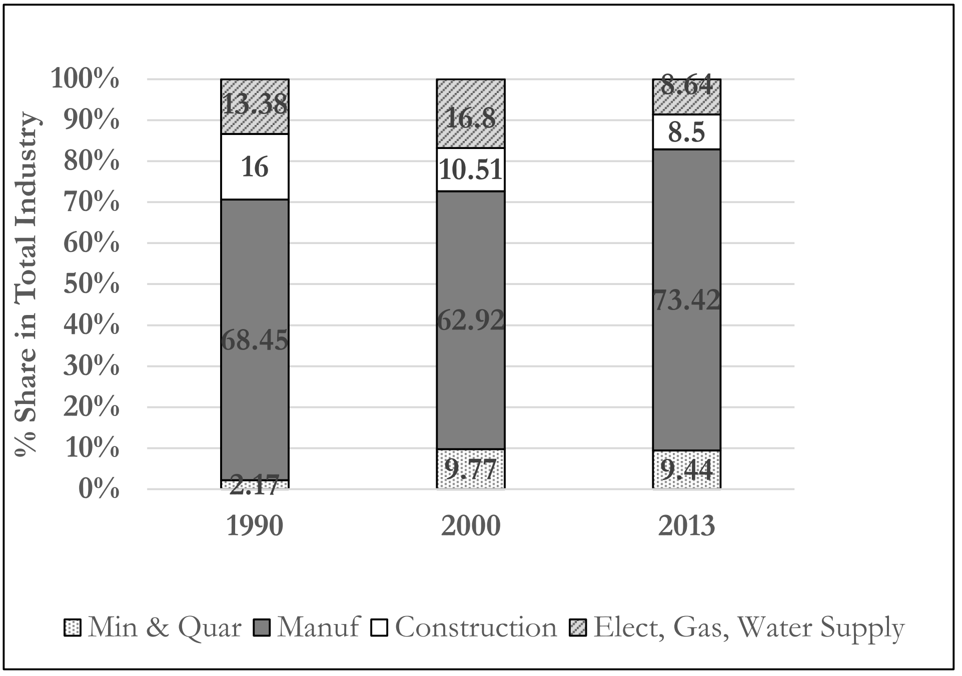
Source: Pakistan Economic Survey (Various Issues)

Figure 4. Sub-sector share in Agriculture Output



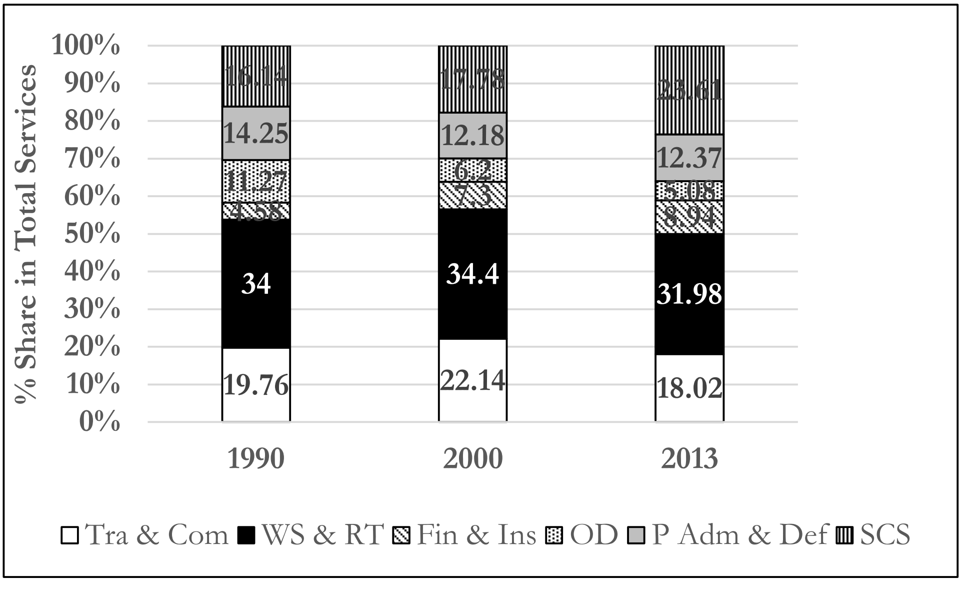
Source: Pakistan Economic Survey (Various Issues)

Figure 5. Sub-Sector Share in Industrial Output in Pakistan (%)



Source: Pakistan Economic Survey (Various Issues)

Figure 6. Sub-Sector Share in Services Output (Percentage)



Source: Pakistan Economic Survey (Various Issues)

Figure 6 shows sub-sectoral shares in the services. Finance and insurance sub-sectors have doubled over the period 1990-2013 whereas, social and other community services rose from 16% to 24%. The analysis shows that energy use, composition of energy sources, and sectoral share in energy consumption is changing. It signifies the importance of investigating energy consumption trends across different sectors to formulate an optimal energy supply system in the country. This analysis will help in understanding the energy consumption behaviour vis-à-vis the requirements for infrastructure and future planning for making the desired energy sources available in sufficient amounts. The analysis will also guide the policy makers to plan for sustainable energy future in the country.

3. METHOD OF DECOMPOSITION AND DATA

During the last two decades, several studies decompose the changes in energy consumption into specific predetermined effects to capture the factors that may explain the change over a period of time [Choi, *et al.* (1995); Ang and Liu (1995); Ang and Lee (1996); Hoekstra and Bergh (2003); Liu and Ang (2003); Ang, *et al.* (2004); and Reddy and Ray (2010); Ullah, *et al.* (2014)]. Ang and Zhang (2000) and Ang (2004) provide a survey of literature on several decomposition methods including LMDI, AMDI-1, Modified Fisher Ideal Index method, Conventional Fisher Ideal Index method, Shapley/Sun method and Marshall-Edgeworth method. Past studies distinguish between two alternative techniques of decomposition, i.e., structural decomposition analysis (SDA) and index decomposition analysis (IDA). SDA method is based on input-output coefficients, while IDA is based on aggregate input-output data. Ang and Lee (1996) extend the energy consumption approach by replacing it with energy coefficient approach where the impact of structural and sectoral energy efficiency changes are measured in terms of coefficients and elasticities.

IDA is useful to decompose the change in aggregate variables in two or more different components with their shares in the aggregate change. LMDI is one of the index based techniques of IDA [Ang and Zhang (2000)]. An LMDI with both multiplicative and additive techniques is proposed by Ang and Choi (1997). LMDI has been extensively used for decomposition of energy consumption in different countries and identified the impact of predefined factors in energy consumption change Ediger and Huvaz (2006); Ma and Stern (2008); Hatzigeorgiou, *et al*. (2008); Mairet and Decellas (2009); Zhang, *et al*. (2011); and Zhao, *et al*. (2012)]. In some of the studies, sectoral effects representing a transition from agriculture to industrialization explains increase in energy demand [Lotz and Pouris (2012); Zhao, *et al.* (2012)], while in many other studies, activity effect is the main driver of change in aggregate energy consumption [Balezentis, *et al.* (2011); Nasab, *et al.* (2012)]. Hasabeigi, *et al.* (2012) incorporate additive LMDI approach for decomposing energy intensity of Californian industries for the period 1997-2008 and find that structural effect that cause a shift from high energy intensive industries to low energy intensive industries play an important role in reduction of energy intensity.

Among different IDA techniques, LMDI is found to be a superior decomposition method in various past studies Ang and Liu (2001); Ang (2004); and Ang (2005); Xu and Ang (2014). Ang, *et al*. (2004)] compare LMDI results with many other methods including (AMDI)-1, Conventional and Modified Fisher Ideal Index method, Shapley/Sun method and Marshall-Edgeworth method, Simple Average Parametric Divisia Index, Laspeyres Index, and Divisia Index Arithmetic Mean Function and find that LMDI is preferable on the basis of properties like theoretical foundation, ease of use, result interpretation and adaptability. Ang and Liu (2001, 2007) reiterate that LMDI a better decomposition method with no residual term (an overview of some of the selected studies on the energy decomposition is given in Annexure). Other identified features of LMDI include comprehensive formula, error free decomposition, perfect aggregation and capability of handling zero values in the data set. Due to these merits, both multiplicative and additive LMDI are considered superior to other methods. Therefore, we employed LMDI for decomposing total energy consumption in Pakistan.

Decomposition is a top down approach that has been greatly used for apportioning the aggregates into different components. This study aims to investigate the factors that are accountable for change in aggregate energy consumption in Pakistan for the period 1990-2013 method. The total energy consumption is decomposed using LMDI for three periods of different lengths, (i) the analysis for overall period that is, 1990 to 2013; (ii) 1990-2000; and (iii) 2000 to 2013. The first set analyzes the aggregate changes for the whole time period to get historical trends with the year 1990 as a base period and 2013 as a current period. The second and third sets are for the decade-wise analysis, where base years are 1990 and 2000 respectively. Change in aggregate energy use is a long term phenomena hence, we conduct a period-wise decomposition rather than time series decomposition. The analysis classifies the overall economy into three major sectors including agriculture, industry and services. Main variables in the data set are the final energy consumption in Tonnes of Oil Equivalent (TOE) and output level (GDP in million rupees) for all the three sectors. Sector-wise energy consumption data is obtained from *Hydrocarbon Development Institute of Pakistan* (Unpublished) and collected from *Pakistan Energy Yearbook* (Published). The economic activity data are collected from various issues of *Pakistan Economic Survey*.

The study employs IDA based method of LMDI proposed by Ang and Choi (1997) and Ang (2005). LMDI is based on an identity, where the left-hand-side must equal the right-hand-side making a decomposition model with no residual. There are two main approaches in LMDI: (a) ratio decomposition also known as multiplicative decomposition and (b) difference decomposition also known as additive decomposition. In this study, the latter is adopted, as the former gives results in ratio form that are difficult to interpret. The method examines the impact of pre-defined effects explaining the change in total energy consumption in absolute form by adding all the factors on right-hand side of the identity. The overall change is divided into the above mentioned three effects as defined below:

1. Activity effect refers to the change in aggregate energy consumption due to change in overall activity level.
2. Structural effect refers to the change due to a change in activity mix by a sub-sector.
3. Intensity effect refers to the use of energy per million rupees of output.

Let the total energy change be represented by G, assuming that there are a number of factors represented by n associated with change in the aggregate over the period of time with quantitative variables, i.e., x_1, x_2, x_3, ..., x_n. The subscript i represents sub-sector. The general IDA identity is given as follows:

$$\sum_{i=1}^{n} G_i = \sum_{i=1}^{n} x_{1i}, x_{2i}, \ldots, x_{ni} \qquad \ldots (1)$$

The aggregate change from G^0 to G^T takes the form:

$$G^0 = \sum_{i=1}^{n} x_{1i}^{o}, x_{2i}^{o}, \ldots, x_{ni}^{o} \text{ and } G^T = \sum_{i=1}^{n} x_{1i}^{T}, x_{2i}^{T}, \ldots, x_{ni}^{T}$$

where, 0 is the base period and T the current period. Decomposition through additive technique takes the following form.

$$\Delta D_{Tot} = G^T - G^0 = \Delta Gx_1 + \Delta Gx_2 + \ldots + \Delta Gx_{n.} \qquad \ldots (2)$$

Additive decomposition gives results in absolute form by adding all the factors on the right-hand-side making them exactly equal to the left-hand-side of the identity. The general LMDI formula for the *kth* factor in Equation (2) is as follows:

$$\Delta G_{xk} = \sum_{i=1}^{n} L(G_i^T\ G_i^0) ln\ (xk_i^T / xk_i^0) \qquad \ldots (3)$$

The IDA for the three factors case is given below,

$$E = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} Q\ \frac{Qi}{Q}\frac{Ei}{Qi} = \sum_i QS_iI_i \qquad \ldots (4)$$

where,
E = The total energy consumption of all the sectors in the economy
$Q = \sum_i Q_i$ is the total economic activity/output level of all sectors in the economy
Q_i is the output level of the i^{th} sector
$S_i = Q_i/Q$ is the activity share of the i^{th} sector
E_i is the energy consumption of the i^{th} sector

$I_i = E_i / Qi$ is the energy intensity of the i^{th} sector

For additive decomposition, we decompose the difference such as,

$$\Delta E_{TOT} = E^T - E^0 = \Delta E_{Act} + \Delta E_{Str} + \Delta E_{Int} \quad \text{... (5)}$$

where,

ΔE_{TOT} denotes aggregate change in energy consumption,

E^T denotes energy consumption in current year,

E^0 denotes energy consumption in base year,

ΔE_{Act} denotes change in energy consumption due to activity effect,

ΔE_{Str} denotes change in energy consumption due to structural effect,

ΔE_{Int} denotes change in energy consumption due to intensity effect.

Three effects on right-hand-side of the Equation (5) are estimated by employing the following Equations:

$$\Delta E_{Act} = \sum_i \left[Wi \; * \; ln \left(\frac{Q^T}{Q^0} \right) \right] \quad \text{... (5a)}$$

$$\Delta E_{Str} = \sum_i \left[Wi \; * \; ln \left(\frac{Si^T}{Si^0} \right) \right] \quad \text{... (5b)}$$

$$\Delta E_{Int} = \sum_i \left[Wi \; * \; ln \left(\frac{Ii^T}{Ii^0} \right) \right] \quad \text{... (5c)}$$

where,

$$Wi = \frac{E^T - E^0}{ln\, Ei^T - ln\, Ei^0}$$

To calculate activity effect (ΔE_{Act}) for the three sectors, we divide total current period output by total base period output for all three sectors (Q^T/Q^0) and take their natural log. The results are multiplied to aggregate W_i of all the three sectors that gives us final value for activity effect. The structural effect (ΔE_{Str}) is calculated for the three sectors by dividing the current period output share of the i^{th} sector in total output by base period output share of the same sector in total output, i.e., (S_i^T/S_i^0). Similarly, intensity effect (ΔE_{int}) is calculated for the three sectors by dividing the current period energy intensity of the i^{th} sector by base period energy intensity of the same sector, i.e., (I_i^T/I_i^0). The sum value of three Equations (5a), (5b) and (5c) must be equal to the term $\Delta E = E^T - E^0$ in Equation (5).

4. RESULTS AND DISCUSSIONS

The study is carried out for three time periods using methodology described in Section 4. First analysis gives us overall energy consumption decomposition for the whole period of 1990-2013. Table 1 shows the decomposition results for all three periods. In each period, the first row show decomposition results in absolute form with unit of energy consumption change, while second row shows the relative contribution of the three effects in total change in percentage form. The total change in energy consumption is 18.603 MTOE by taking 1990 as base year and 2013 as current year. The dominant contribution of 159.97% comes from activity effect with 29.780 MTOE.

Intensity effect is the second dominant contributor having a share of -12.722 MTOE, implying 68% reduction in overall change in energy consumption, thus compensating the inflated demand of energy use driven by activity and structural effects. It means that energy intensity has decreased leading to a contraction of 12.722 MTOE in overall energy change. Since energy intensity is inversely related to energy efficiency, a decrease in energy intensity implies a rise in energy efficiency. Several factors that contribute directly and indirectly towards energy efficiency are innovative energy saving policies such as promotion of energy efficient appliances, growth of natural gas consumption and LPG in all the three sectors of economy during the period.

The third contribution of 8.41% with 1.565 MTOE in total change comes from structural effect, showing that structure of the economy experienced slight transition from agrarian to industrial and services dominated economy. The sectoral composition of the economy changed especially in the 2000s. The share of agriculture in economy falls by 17% between 1990 and 2013. The shares of industry and services sector increase by 10% and 5% respectively during the period. Statistics show structural shift from low energy intensive agriculture sector to high energy intensive industrial and service sector thus contributing in rise of energy consumption.

The overall increase of energy consumption is dominantly contributed by services and industrial sector. The cumulative effects of service sector indicate that this sector is responsible for 12.501 MTOE in total change. Similarly, industrial sector is responsible for an increase of 6.937 MTOE in total energy consumption over the period 1990-2013. Agriculture is responsible for a slight decline of 0.835 MTOE in the overall change. The sector wise decomposition analysis shows a decline of -0.835 MTOE in agriculture sector. Activity effect is responsible for an increase of 1.022 MTOE due to growth in agriculture sector, while structural and intensity effects dominantly decrease the total change. Structural pattern also indicates within sector transition from energy intensive crop sector towards less energy intensive livestock sector.

A rise of 6.937 MTOE in industry is mainly due to activity effect followed by structural effect having share of 150% and 14% respectively. Due to growth in industrial sector, activity effect is the main source of growth in energy consumption. Structural effect shows that industrial sector has been changing its sub-sector composition with rising share of mining, quarrying and manufacturing. The compensating share of 63% is reflected through intensity effect with decline of 3.689 MTOE in total industrial energy consumption change. It means industrial sector has witnessed energy efficiency due to modern techniques of production, change in sub-sectoral composition with slight shift from more energy intensive sub-sectors to less energy intensive sub-sectors as mentioned in Figure 5.

An increase of 12.501 MTOE in services sector is mainly attributed to activity and structural effects with share of 147% and 7% respectively. Due to growth in services sector, activity effect is responsible for 18.325 MTOE rise in total sectoral energy consumption change. The structural changes in sub-sector composition of services sector as shown in Figure 6, is captured by a rising share of sub-sectors like finance and insurance and social and community services in total service industry over the period 1990-2013. Intensity effect has compensating share of 53% causing total energy consumption change decrease by 6.56 MTOE. Energy efficiency in services sector is mainly attributed to shift from high energy intensive subsectors to less energy intensive subsectors. The dominant share of service sector in total energy use implies that energy is used as a final good to maximize well-being although it may not directly generate economic activity.

Table 1 shows the results of total change in energy consumption which stands at 3.70 MTOE over the period 1990-2000. The dominant factor behind this change is activity effect followed by intensity effect. Activity effect (ΔE_{Act}) is responsible for 278% increase in total change equivalent to 10.28 MTOE. The second dominant contributor is intensity effect (ΔE_{Int}) with -6.51 MTOE holding a share of -175.85% in overall change. The contribution of structural effect (ΔE_{Str}) is negligible with 0.066 MTOE (1.77%) decline in overall energy consumption change. Figure 3 shows that sectoral composition of Pakistan economy in the 1990s was traditional with little structural shifts towards industrialization. The negative contribution of structural effect in overall energy consumption change is due to slight decrease in the service sector share. To summarize, the total change of 3.703 MTOE is dominantly contributed by services and industry. The cumulative effects of services sector is 3.179 MTOE followed by industrial with 1.344 MTOE in total increase. Agriculture sector is responsible for a decrease of 0.820 MTOE in overall change in this period.

Table 1. LMDI Decomposition Results of Pakistan Economy: 1990-2013

Category (Unit)	ΔE_{Act}	ΔE_{Str}	ΔE_{Int}	ΔE_{TOT}
		1990-2013		
Absolute change (MTOE)	29.78	1.565	-12.722	18.603
Share in change (%)	159.97	8.41	-68.38	100
		1990-2000		
Absolute change (MTOE)	10.282	-0.066	-6.513	3.703
Share in change (%)	277.62	-1.77	-175.85	100
		2001-2013		
Absolute change (MTOE)	17.98	1.900	-4.986	14.90
Share in change (%)	120.71	12.75	-33.46	100

The structural and intensity effect results for the Period 2000-2013 are different as compared to preceding period. Structural effect has a higher share of 12.75 % in the energy consumption change as compared to -1.77 % in 1990s which clearly shows that economy had experienced structural changes. The share of intensity effect falls from 176% in the 1990s to just 34% in the 2000s, which shows that energy efficiency still provide relief to inflating energy consumption but its share is declining.

During 2000-2013, total energy consumption increases by an amount of 14.90 MTOE. Due to fast pace economic growth in the mid-2000s, the activity effect is the major contributor having share of 17.98 MTOE (121%). The share of activity effect in overall energy consumption falls from 278% to 114% during 2000-2013 as compared to 1990-2000 implying that rapid growth was absorbed and spread by structural and intensity effects. The share of structural effect in total change has increased from 1.77% in 1990s to 13% in this period. Intensity effect is the most considerable factor in this period, showing low trends of energy efficiency. In this period, intensity effect is responsible for a decline in overall energy consumption change equivalent to 4.98 MTOE (33%).

Table 2 shows sector-wise decomposition results. The agriculture sector is responsible for 0.820 MTOE decline in total energy consumption change mainly due to structural and intensity effects. Activity effect explains the change in energy consumption by 0.45 MTOE (55%) mainly due to growth in agriculture sector. Intensity effect has compensating share of 1.28 MTOE (157%) using decrease in total agricultural energy consumption. Energy efficiency is mainly due to shift from high energy intensive crop sector to low energy intensive livestock sector along with the modernized farming techniques and energy efficient farm machinery. The table shows a rise of 1.344 MTOE in industrial sector's energy consumption, due to activity and structural effects and compensating intensity effect. The activity effect is responsible for 262% increase in energy consumption accruing from growth in the industrial sector. Structural effect accounts for 6% share in total industrial energy consumption change. The industrial sector has witnessed energy efficiency as depicted by a compensating share of 168% in total change. Modern production techniques, energy saving machineries, high value added output and changing sub-sector composition of industrial sector are the main reasons of energy efficiency in the industrial sector.

An increase of 3.179 MTOE in services sector is mainly due to activity effect with a share of 198.43%. Structural and intensity effect has compensating share of 5% and 93% respectively due to changing sub-sectoral shares. Last panel of Table 2 shows an increase of 14.90 MTOE in 2000-2013, which is dominantly contributed by services and industrial sector. The combined effect of services sector is 9.32 MTOE followed by industrial sector with 5.59 MTOE over this period. The effect of agriculture sector is negative with a decrease of 0.015 MTOE in overall energy consumption change.

Table 2. Sector wise LMDI Decomposition Results of Pakistan Economy 1990-2013

Sector	ΔE_{Act} *(MTOE)*	ΔE_{Str} *(MTOE)*	ΔE_{Int} *(MTOE)*	ΔE_{TOT} *(MTOE)*	ΔE_{Act} %	ΔE_{Str} %	ΔE_{Int} %	*Total %*
1990-2013								
Agriculture	1.02	-0.209	-1.59	-0.84	-122.35	23.93	198.41	100
Industry	10.41	0.938	-3.68	6.94	150.09	13.52	-63.62	100
Services	18.32	0.827	-6.56	12.50	146.58	6.61	-53.20	100
Total (MTOE)	29.76	1.565	-11.84	18.60	_	_	_	_
1990-2000								
Agriculture	0.45	0.013	-1.28	-0.82	-55.47	-1.65	157.12	100
Industry	3.51	0.081	-2.25	1.34	261.63	6.35	-167.99	100
Services	6.30	-0.162	-2.96	3.18	198.43	-5.17	-93.25	100
Total (MTOE)	10.28	-0.064	-6.51	3.70	_	_	_	_
2001-2013								
Agriculture	0.37	-0.139	-0.25	-0.015	-2483	927.29	1655.75	100
Industry	6.28	0.891	-1.58	5.59	112.33	15.94	-28.28	100
Services	11.33	1.148	-3.16	9.32	121.53	12.31	-33.85	100
Total (MTOE)	17.98	1.900	-4.98	14.90	_	_	_	_

Sector-wise decomposition results show that compensating 0.015 MTOE change in the agriculture sector is attributed to structural effect (927%) and intensity effect (1656%). Activity effect is responsible for an increase of 0.37 MTOE in total change in agricultural sector energy consumption due to the sectoral growth. Structural shifts are responsible for decrease of 0.14 MTOE. Intensity effects also have compensating share of 0.24 MTOE in the total change arising mainly from change in sub-sector composition. The activity and structural effects with share of 112% and 16% respectively account for an increase of 5.59 MTOE in the industrial sector. Activity effect is responsible for an increase of 6.28 MTOE in total industrial energy consumption change due to growth in that sector. Intensity effect has compensating share of 3.16 MTOE, indicating energy efficiency achievements in industrial sector. A rise of 9.32 MTOE in services sector is contributed by activity and structural effects with share of 122% and 12%, respectively. Activity effect brings about 11.33 MTOE increase in total service sector energy consumption change due to massive growth particularly in the mid-2000s. Change in sub-sector composition is responsible for an increase of 1.148 MTOE through structural effect. Energy efficiency brings a compensating share of 3.16 MTOE reduced through the intensity effect.

5. IMPACT OF ENERGY IMPORTS ON PAKISTAN EXTERNAL ACCOUNT

Pakistan is a net energy importer and relies both on domestic and imported resources to meet its requirements. Natural gas, oil and hydroelectricity account for about 90% of energy supply in the country. The government regulates the distribution of almost all major energy sources. Natural gas supply is made out of domestic resource and often its supply falls short of demand especially during the peak demand season. In that case, oil or LNG imports satisfy excess demand and bring the market into equilibrium. However, heavy share of imports in total energy consumption puts pressure on the balance-of-payments account. Some earlier studies highlight the impact of energy imports on the external account of Pakistan [Malik, 2007; Jamil (2012)]. The dependence on imported energy will further increases due to depleting domestic resources in future that will create negative impact on country's external account. Jamil (2012) argues that internal energy policy and regulations are causing a shortage of indigenous energy resources that resulted in increased imports earlier than it is binding. Hussain (2010) also argues that planning of energy supply composition should integrate the external cost of energy use.

Sustainable and affordable energy supply drives to economic growth and well-being. The rising demand for fossil fuels and its price volatility put extra burden on energy importing economies and make energy sector management and planning quite challenging. Energy security especially in uncertain international oil market has been an important political and economic concern. Energy dependence to fulfill the total energy requirement can be measured as net energy import as percent of total energy consumption. High energy dependence leads a country to vulnerability with negative impacts on foreign exchange reserves and expose the economy to international economic shocks.

The world is facing serious challenges to sustainably meet its growing energy requirements and Pakistan, being an energy deficient country, finds it hard to ensure reliable energy supplies. The rising energy demand coupled with limited and depleting domestic energy resources has unfolded since the mid-2000s. According to SBP Annual Report 2012-13, Pakistan spent approximately USD 14.9 billion (33% of total imports) on petroleum imports with a quantity of 17.9 MTOE. According to Pakistan Integrated Energy Plan 2012-2025, if GDP grows at the rate 2-4%, then the final energy consumption of Pakistan will reach 142 MTOE by 2025 with cumulative growth rate of almost 250% (equivalent to 40 MTOE).

For many years, the country meets only 20% of its total oil requirements through domestic production and the rest is imported. Keeping the same ratio of 80:20 till 2025 implies that the country will require to import 32 MTOE of oil which is equivalent to 220.8 million barrels per annum. The forecasted world oil price for 2025 is $100/barrel, taken from the World Bank commodity price index. At price $100/barrel, Pakistan will have to spend $22.85 billion on oil imports by 2025. It is pertinent to note that any increase in price of crude oil may further increase the import bill.

According to Pakistan Integrated Energy Plan 2012-2025, by the year 2025, Pakistan will also require 10.12 billion cubic feet per day (BCFD) of natural gas with expected domestic production of 2.17 BCFD. The imports of 7.95 BCFD will be equivalent to 2992 million British thermal Unit (MBTU) per annum. If the international price of gas forecasted by the World Bank Commodities Price Forecast remains $10/BTU, Pakistan will have to spend $ 29.92 billion by 2025. Table 3 shows the impact of projected imports on external account in 2025. Projected estimates show that the country will have to spend $52.76 billion on imports of oil and gas by 2025. The total value of oil and gas imports in 2013 were $14.9 billion that will witness a growth of 250% by 2025.

Table 3. Import Bill based on Projections

	Domestic	Imports	Total	World Price	Value ($ billion)
Oil 2025 (MTOE)	8	32	40	$ 100/barrel	22.85
Gas 2025 (BCFD)	2.17	7.95	10.12	$ 10/(MBTU)	29.91
Oil 2013 (MTOE)	11.3	19	30.3	$ 107/barrel	14.9

Sources: Pakistan Integrated Energy Plan, 2012-2025, Pakistan Energy Year Book, HDIP, 2013, WB Commodity Price Forecast, 2015.

High dependence on imported energy will further expose the economy to vulnerability with interrupted energy supplies and price shocks especially in international oil market. The negative impacts of $52.76 billion worth imports will severely reflect through both internal account (budget) and external account (balance of payment). The ever rising-energy imports have serious implications for an economy with trade deficits. In consideration of limited foreign exchange reserves, there is a need to reduce our dependence on energy imports by domestic resource mobilization, through inflow of foreign direct investment, efficient use of available energy resources, and balanced energy mix. Energy conservation is the best method to lower the energy supply and demand deficit. Currently, Pakistan has the potential to save 25 % of energy on average worth $5billion annually [ENERCON (2015)].

6. CONCLUSION

This study provides a comprehensive analysis of the factors responsible for growing energy consumption in Pakistan over the period 1990-2013 with segmented time period analysis using LMDI decomposition technique. Finding the determinants of change in overall energy consumption is important for appropriate energy policy design and its implementation. In Pakistan energy mix is mainly comprised of four fuel types; natural gas, oil, hydroelectricity and coal. LMDI technique tracks down the pre-defined determinants (activity effect, structural effect and intensity effect) responsible for increased energy consumption in three major sectors.

Total energy consumption in Pakistan increased by 86.2% (equivalent to 18.60 MTOE) over the period 1990-2013. Even so, there is prevalence of enormous unmet energy demand due to natural gas and electricity shortage especially since the mid-2000s. The energy shortage is a result of the domestic energy market control by the government, who are responsible for overall energy planning and influence the prices and quantity supplied to different sectors. This increase is mainly due to the activity effect followed by an intensity effect. By 2025, the final energy consumption is projected to reach 142 MTOE level. In analysis of the period 1990-2013, activity effect is found to be the main contributor in overall energy consumption growth, which reiterates the positive relationship between economic growth and energy consumption. Intensity effect is the second major compensating contributor in the overall energy consumption change showing strong indications of energy efficiencies in overall economy as well as in sector wise analysis. The share of structural effects are low in volume but indicates that the economy experiences a slow pace structural shift from traditional economy to industrialized and service-led economy.

Analysis of the period 1990-2000 shows the highest share of energy efficiency through intensity effect in the overall change. Activity effect remains the most dominant contributor in the overall energy consumption change with services and industrial sectors holding the dominant share in overall activity effect. The share of structural effects is very little due to stagnant sectoral composition of economy over this period. The compensating share of intensity effect in total energy consumption is comparatively less than the preceding period showing an overall slowdown energy efficiency.

The quantification of energy imports based on projections shows that Pakistan faces serious challenge of rising import bill due to dwindling domestic energy reserves and energy price volatility. The findings of our study are consistent with various past studies conducted for different countries mentioned in literature review [Ediger and Huvaz (2006); Mairet and Decellas (2009); Sahu and Narayanan (2010); Zhang, *et al.* (2011); and Nasab, *et al.* (2012)]. The decomposition findings of Pakistan economy is consistent with other developing countries in which activity and intensity effect contribute dominantly with structural effects up to some extent. The findings of this study provide basic foundations for energy related policies both in their formulation as well as implementation. For policy makers, the result of energy intensity effect is startling as it shows an increase in energy intensity during recent decade, which is a sign of concern. In order to reduce gap between energy demand and supply, energy conservation is the best and cheapest method as Pakistan has potential to save sufficient energy. Furthermore, the petroleum exploration policies should be designed judiciously to attract investment in order to reduce import dependence.

Annexure

List of Selected Studies on Energy Decomposition

Study	Country	Method	Sector	Effects/Factors
Choi, *et al.* (1995)	Korea	Divisia Index	Manufacturing	Aggregate intensity
Ang and Lee (1996)	Singapore Taiwan	Energy Coefficient Approach	Electricity	Sectoral intensity
Ediger and Huvaz (2006)	Turkey	LMDI	Whole Economy	Sectoral
Ma and Stern (2008)	China	LMDI	Whole Economy	Technological
Mairet and Decellas (2009)	France	LMDI	Services	Activity
Sahu, and Narayanan (2010)	India	General Parametric Divisia Index and Laspeyers Decomposition Index	Manufacturing	Structural Intensity Activity
Zhang, *et al.* (2011)	China	LMDI	Transport	Activity Intensity

Balezentis and Strienikiene (2011)	Lithuania	LMDI	Whole Economy	Intensity
Nasab, *et al.* (2012)	Iran	LMDI	Industrial	Activity Structural Intensity
Hasabeigi and Sathaye (2012)	California	LMDI	Industrial	Structural
Zhao, *et al.* (2012)	China	LMDI	Residential	Income Structural Intensity Activity Population
Lotz and Pouris (2012)	South Africa	LMDI	Whole Economy	Structural
Ullah, *et al.* (2014)	Pakistan	Fischer Ideal Index (IDA)	Whole Economy	Intensity

REFERENCES

Ang, B. W. and F. Q. Zhang (2000) A Survey of Index Decomposition Analysis in Energy and Environmental Studies. *Energy*, 25:12, 1149-1176.

Ang, B.W. (2004) Decomposition Analysis for Policy Making in Energy: Which is the Preferred Method? *Energy Policy*, 32, 1131-1139.

Ang, B.W. (2005) The LMDI Approach to Decomposition Analysis: A Practical Guide. *Energy Policy*, 33:7, 867-871.

Ang, B.W. and K. H. Choi (1997) Decomposition of Aggregate Energy and Gas Emission Intensities for Industry: A Refined Divisia Index Method. *The Energy Journal*, 18:3, 59-73.

Ang, B.W. and P.W. Lee (1996) Decomposition of Industrial Energy Consumption: The Energy Coefficient Approach. *Energy Economics*, *18*, 129-143.

Ang, B.W. and F.L. Liu (2001) A New Energy Decomposition Method: Perfect in Decomposition & Consistent in Aggregation. *Energy, 26*, 537-548.

Ang, B.W. and N. Liu (1995) Decomposition Methodology in Industrial Energy Demand Analysis. *Energy*, 20:11, 1081-1095.

Ang, B.W. and N. Liu (2007) Negative-Value Problems of the Log Mean Divisia Index Decomposition Approach. *Energy Policy*, 35:1, 739-742.

Ang, B.W. and F.Q. Zhang (2000) The LMDI Approach to Decomposition Analysis: A Practical Guideline. *Energy Policy*, 33:7, 865-871.

Ang, B.W., Liu, F.L. and S.H. Chung (2004) A Generalized Fisher Index Approach to Energy Decomposition Analysis. *Energy Economics*, 26:5, 757-763.

Apergis, N. and J.E. Payne (2010) Energy Consumption and Growth in South America: Evidence from a Panel Error Correction Model. *Energy Economics*, 32:6, 1421-1426.

Balezentis, A., Balezentis, T. and D. Streimikiene (2011) The Energy Intensity in Lithuania during 1995-2009: A LMDI Approach. *Energy Policy*, 39:11, 7322-7334.

Belke, A., Dobnik, F. and C. Derger (2011) Energy Consumption and Economic Growth: New Insights into the Cointegration Relationship. *Energy Economics*, 33:5, 782-789.

Ediger, V.S. and O. Huvaz (2006) Examining the Sectoral Energy Use in Turkish Economy: (1980–2000) With the Help of Decomposition Analysis. *Energy Conservation and Management*, 47:6, 732-745.

ENERCON (2015) Government of Pakistan. Available at: http://www. enercon.gov.pk/index.php?option=com_content&view=article& id=28&Itemid=27.

HDIP (2000, 2014), *Energy Yearbook*, Hydrocarbon Development Institute of Pakistan, Government of Pakistan, Islamabad.

Hasanbeigi, A., Can, S.D.L. and J. Sathaye (2012) Analysis and Decomposition of the Energy Intensity of California Industries. *Energy Policy*, 46, 234-245.

Hatzigeorgiou, E., Polatidis. and D. Haralambopoulos (2008) CO2 Emissions in Greece for 1990-2002: A Decomposition Analyses & Comparison of Results Using the Arithmetic Mean Divisia Index & Logarithmic Mean Divisia Index Techniques. *Energy*, 33:3, 492-499.

Hoekstra, R. and J.J.C. Bergh (2003) Comparing Structural and Index Decomposition Analysis. *Energy Economics*, 25:1, 39-64.

Hussain, T. (2010) Pakistan's Energy Sector Issues: Energy Efficiency and Energy Environmental links. *The Lahore Journal of Economics*, 15:3, 33-59.

Ministry of Finance (2013) *Integrated Energy Planning and Pakistan's Energy Future: An Update on a Continuing Crisis.* Pakistan Economic Forum, Islamabad.

Jamil, F. (2012) Impact of Different Public E&P Policies on Natural Gas Reserves and Production in Pakistan. *Resources Policy*, 37:3, 368-374.

Jamil, F. and E. Ahmad (2010) The Relationship between Electricity Consumption, Electricity Prices and GDP in Pakistan. *Energy Policy*, 38:10, 6016-6025.

Lee, C. C. (2007) Energy Consumption and Economic Growth in Asian Economies: A More Comprehensive Analysis using Pannel Data. *Resource and Energy Economics,* 30:1, 50-65.

Liu, F.L. and B.W. Ang (2003) Eight Methods for Decomposing the Aggregate Energy Intensity of Industry. *Applied Energy,* 76:1, 15-23.

Lotz, R.I. and A. Pouris (2012) Energy Efficiency in South Africa: A Decomposition Exercise. *Energy,* 42:1, 113-120.

Ma, C. and D.I. Stern (2008) China's Changing Energy Intensity Trend: A Decomposition Analysis. *Energy Economics,* 30:3, 1037-1053.

Mairet, N. and F. Decellas (2009) Determinants of Energy Demand in the French Service Sector: A Decomposition Analysis. *Energy Policy,* 37:7, 2734-2744.

Malik, A. (2007) How Pakistan is Coping with the Challenge of High Oil Prices. *The Pakistan Development Review, 46*:4, 551-575.

Masih, A. M. and R. Masih (1996) Energy Consumption, Real Income and Temporal Causality: Results From a Multi-Country Study Based on Cointegration and Error-Correction Modelling Techniques. *Energy Economics,* 18:3, 165-183.

Ministry of Finance (1991, 2001 & 2014), Pakistan Economic Survey, Ministry of Finance, Government of Pakistan, Islamabad

Nasab, E.H., Aalami, R., Dahr, S.F. and M. A. Sadeghzadeh (2012) An Analysis of Energy Consumption in Transportation & Industrial

Sectors- A Multiplicative LMDI Approach with Application to Iran. *Iranian Economic Review*, 16:32, 1-17.

Reddy, B. S. and B. K. Ray (2010) Decomposition of Energy Consumption and Energy Intensity in Indian Manufacturing Industries. *Energy for Sustainable Development*, 14:1, 35-47.

Sahu, S. K. and K. Narayanan (2010) Decomposition of Industrial Energy Consumption in Indian Manufacturing: The energy intensity approach. *Journal of Environmental Management & Tourism*, 1:1, 22.

Shahbaz, M., Zeeshan, M. and T. Afza (2012) Is Energy Consumption Effective to Spur Economic Growth in Pakistan? New Evidence from Bounds Test to Level Relationship & Granger Causality Tests. *Economic Modelling*, 29:6, 2310-2319.

Soytas, U. and R. Sari (2003) Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets. *Energy Economics*, 25:1, 33-37.

Ullah, A., Khan, K., and M. Akhtar (2014) Energy Intensity: A Decomposition Exercise for Pakistan. *Pakistan Development Review*, 53:4, 531-548.

Xu, X.Y. and B.W. Ang (2014) Analyzing Residential Energy Consumption using Index Decomposition Analysis. *Applied Energy*, 113, 342-351.

Zhang, M., Li, H., Zhou, M. and H. Mu (2011) Decomposition Analysis of Energy Consumption in Chinese Transportation Sector. *Applied Energy*, 88:6, 2279-2285.

Zhao, X., Li, N. and C. Ma (2012) Residential Energy Consumption in Urban China:A Decomposition Analysis. *Energy Policy*, *41*, 644-653.